NEXT GENERATION NGST SPACE TELESCOPE

Next Generation Space Telescope Integrated Science Module Data System

Richard G. Schnurr, Matthew A. Greenhouse, Matthew M. Jurotich, Raymond Whitley, Keith J. Kalinowski, Bruce W. Love, Jeffrey W. Travis - NASA Goddard Space Flight Center, Greenbelt MD
Knox S. Long - Hubble Space Telescope Science Center, Baltimore MD

Introduction

The Data system for the Next Generation Space Telescope (NGST) Integrated Science Module (ISIM) is the primary data interface between the spacecraft, telescope, and science instrument systems. This poster includes block diagrams of the ISIM data system and its components derived during the pre-phase A Yardstick feasibility study. The poster details the hardware and software components used to acquire and process science data for the Yardstick instrument compliment, and depicts the baseline external interfaces to science instruments and other systems. This baseline data system is a fully redundant, high performance computing system. Each redundant computer contains three 150 MHz power PC processors. All processors execute a commercially available real time multi-tasking operating system supporting, preemptive multi-tasking, file management and network interfaces. These six processors in the system are networked together. The spacecraft interface baseline is an extension of the network, which links the six processors. The final selection for Processor busses, processor chips, network interfaces, and high-speed data interfaces will be made during mid 2002.

Software task diagrams with data flow paths are presented to summarize all aspects of the system. This software configures the instruments for an observing mode, using an event-based scheduler included in the ISIM Data system software. The software also operates custom Field Programmable Gate Array hardware to acquire and process the data from the three Yardstick science instruments, which are operated independently. The software also operates hardware in the ISIM data processor to compress and format the science data into observation file records. These observation files are transferred to the spacecraft data system using a network interface. Non real time software in the ISIM data system computes primary mirror figure and focus commands required to tune the telescope for optimal performance. The ISIM data system software also delivers a real-time fine guidance command derived from processed wide field camera data.

Purpose of Architecture Study

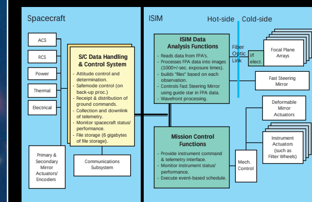
The goal of the NGST ISIM data system pre-phase A activity was to determine whether development of a data system that meets the needs of NGST could be accomplished using the technology expected to be available in the NGST timeframe. Additionally, cost and performance trade studies were performed for FPA sizes from 50 to 400 mega-pixels with readout times of 2 to 15 seconds. Limiting areas were identified and characterized based FPA size and readout time. This work is valuable for future instrument and spacecraft trade studies to be executed during the NGST phase A.

NGST Flight Data System Requirements

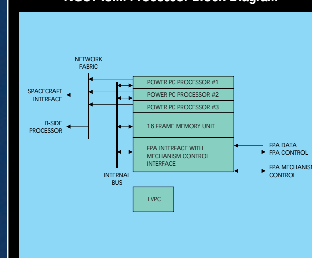
NGST ISIM Data system requirements:
Collect focal plane array data- 5 - 4096 X 4096 arrays and 1-1024X1024 array, 2-15 second readout times. Support ground communications- accept ground and S/C commands and files, send files to ground.
Select and track guide star using a single 1024 X1024 detector in main array. Use guide star data to generate fast steering mirror commands and S/C centering control commands . 100 Hz control loop is required.
Support off-line wave-front processing (mirror figure control) based on focal plane array data. Deformable mirror and Optical Telescope Assembly control commands.
Provide on-board health and safety monitoring of spacecraft and instrument components.
Provide "event driven" (adaptive) science scheduling capability.
Provide instrument command and control capability.

Hardware

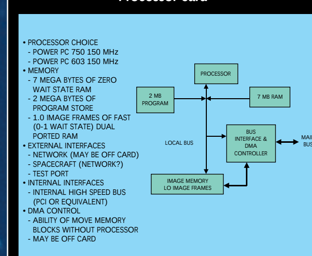
NGST Flight Data System - Block Diagram



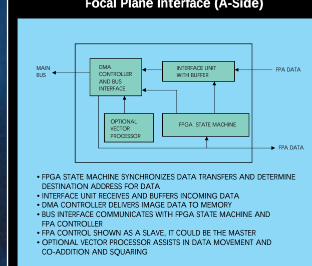
NGST ISIM Processor Block Diagram



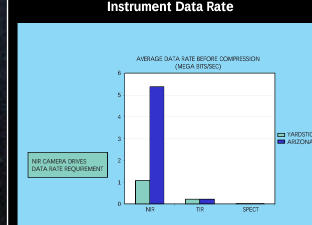
Processor Card



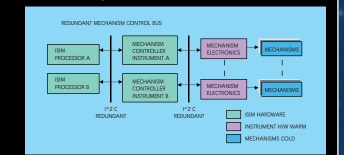
Focal Plane Interface (A-Side)



Instrument Data Rate



FPA Mechanism Control Architecture I Squared C Like Bus Centralized

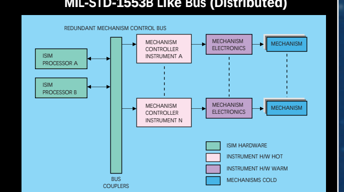


Mechanism Control Trade Issues

Optimum mechanism control scheme drivers:

- Wire restrictions imposed by thermal isolation truss may require a common instrument mechanism control bus
- Power restrictions for warm side electronics may not allow busses like MIL-STD-1553B to be used Power of bus interface chips is high (3-4 watts per interface)
- I squared C may be a good compromise for a mechanism control bus
  - Minimizes impact on thermal truss wiring
  - Industry standard bus
  - Low cost GSE equipment available
  - Simple low power protocol
  - Speed up to 400 kbps
- Hardware / software development cost and simulator development will be a significant cost driver Industry standard bus highly desirable for cost reasons

FPA Mechanism Control Architecture MIL-STD-1553B Like Bus (Distributed)



Benefits of using COTS-like Data System Hardware

Use of flight hardware identical in function to commercially available hardware enables lower system development costs.

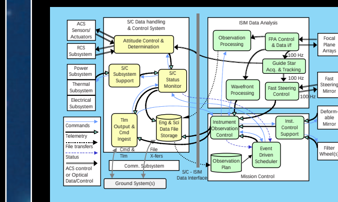
- Power PC architecture baseline because of X2000 Power PC enables the use of commercial software development tools and commercial real time operating systems. Commercial software standards can also be used. Several commercial real time operating systems exist which support Internet Protocols
- Commercial bus architectures will be used where practical to reduce cost and to allow the use of commercial designs and test equipment. Commercial communication interfaces will be used where practical to allow standard off the shelf hardware to be used as simulators.
- Simplifies interface testing by allowing use of commercial interface documentation, test sets, training, and hardware.

ISIM Data Processing Future Work and Questions

- Continue to investigate pixel processing algorithms
- Continue processor, data link and back-plane bus investigations.
- Investigate using independent processors for TIR and spectrometer to reduce software costs
- Develop software integration and test methodologies and asses hardware impacts
- Develop flight code development and test paradigms for use at instrument institutions and asses hardware, software and cost impacts.
- Should algorithms be implemented which exclude "statistically bad sample differences" from slope fit, but which includes these "bad" differences in the data stream to allow the ground to verify or reverse the correction process. (The Jurotich/Knox method.)
- Will a full cosmic ray identification algorithm be implemented in the ISIM data system
- What forms of compression will be used in the NGST ISIM.
  - Need to perform study with actual/simulated NGST/HST data and flight algorithms currently implemented in flight qualified parts.
  - Currently 3.0 to 1.0 compression is baseline. A specific implementation for this compression must be defined during the phase A activities.
  - Current flight qualified compression chips operate at about 2:1 compression ratio
    - NGST compression should be executed in hardware because of high data rate
  - A cost trade including the cost of compression vs the ground and flight systems cost impacts must be performed during as part of the Phase A.
- Define ISIM data system architectures for large arrays at fast readout rates to enable the preparation of a cost model.

Data Processing

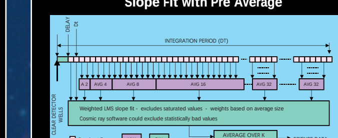
NGST Flight Data System - Data Flow Diagram



Baseline FPA Processing

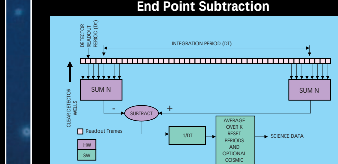
- FPA processing can operate at full detector rate (ie no-dead time)
- FPA processing has been partitioned between hardware state machines and software because of the high pixel counts.
- End point averaging
  - N samples at start added to sum
  - N samples at end subtracted from sum
  - Final sum reported as result
- Slope fit
  - 16 samples or averages of samples, read at irregular intervals over 1000 seconds
  - Slope found using LMS line fit (derivation available)
  - Slope is computed not offset
  - Time of each sample or sample average is required
  - Value beyond linear range are not included in slope
- Both algorithms are implemented with helper hardware
  - End point averaging or sample averaging uses a memory unit with add or subtract to location capability
  - Slope fit is baseline for software but could be implemented in hardware which implements $z = s + x*y$ (could be implemented in dsp)

Slope Fit with Pre Average



- Irregular sampling in time domain reduces computational loading while increasing dynamic range
- Dynamic Range [0, (GAIN * QE * FULL_WELL) / (DELAY + Dt)]
  - About 500 times greater dynamic rage compared to end point averaging
- Avg 2,4,8,16,32 can be implemented in hardware at low cost
- Cosmic ray processing possible for time scales > 32 * Dt
- Science data rate proportional to DT/K
- Average computational requirements: HW (#pixels / Dt) OPS, SW slope fit (10* #pixels)/32 FLOPS

End Point Subtraction



- Dynamic range [0,(Gain * Qe * Full_well) / Dt].
- Science data rate Proportional To Dt / K.
- Average computational requirements: ((2N+2)(#Pixels))/dt (no cosmic ray).
- Processing can be implemented in hardware at low cost for any possible array size.
- Science data is averaged over Dt*k.
- Completely linear system with exception of optional cosmic ray software.

NGST ISIM Cosmic Ray Issues

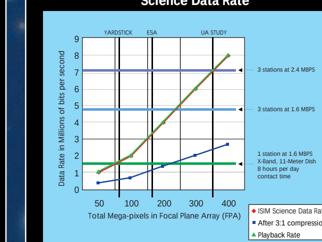
- NGST is in a relatively harsh radiation environment.
  - Currently assuming 10% of all pixels will be impacted every 1000 seconds
- Detector parameters may change after impact.
  - Recovery time is not currently modeled.
- Detecting some cosmic ray events is possible when in slope measurement mode.
  - Compute differences between slope samples.
  - Look for statistical abnormalities in ISIM, (could be quite computationally intensive).
    - Could take transform of difference data to look for abnormal frequency content
    - Could compare pixel with adjacent pixels to look for statistically significant events (tremendous amount of on board processing)
  - What should be done if abnormality is found.
    - Do nothing (loose 1000 + seconds), Clean data using ground processing (baseline)
    - Mark pixel as bad data
    - Exclude from slope algorithm bad differences and differences for TBD additional samples
    - Excluded differences could be included in telemetry to allow bad data to be reconstructed during ground processing
    - Send all the samples for suspect pixels to the ground - generates more data (X 2.6)
- ISIM computer hardware must be customized for cosmic ray cleaning algorithm
- Current baseline does not include computational overhead for cosmic ray cleaning

Processing Requirements

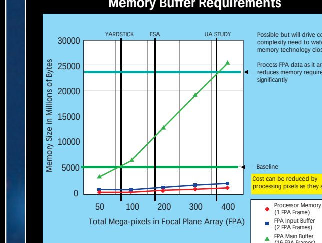
ISIM Yardstick Data System Impacts for Large FPA Arrays

- Average Science data rate will increase proportional to FPA pixel count.
  - Higher down link rate, Ka band, higher power, or more ground stations
  - More compression: 3D lossless compression - No hardware available
- Data rate between FPA electronics and ISIM processor increases proportional to pixel count and inversely proportional to FPA readout time.
  - More fiber cable interfaces required.
  - Develop higher speed flight fiber interface for NGST, (10 Gbit/sec available for ground use)
- Higher processing power required
  - Use lower cost Digital Signal Processor to perform pixel processing
  - Lower cost if more than three Power PC processors are required
  - Flight unit with commercial equal should be selected
- Compression becomes an issue because hardware lossless compression limited to 2 to 1.
  - Higher lossless compression ratios will require pixel compression over time.
- Main bus of ISIM processor must provide sufficient bandwidth. Currently one main bus for each fiber optic FPA interface is required. Processors would be dedicated to certain sections of the FPA. Processors would communicate on a secondary bus like IEEE-1355.

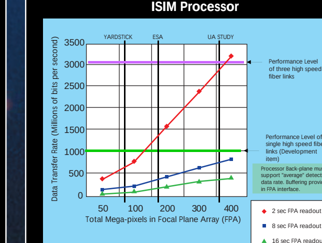
Science Data Rate



Memory Buffer Requirements



Data Rate Between FPA Electronics and ISIM Processor



Processor Requirements